MACROCOGNITION IN TEAMS

Macrocognition in Collaboration and Knowledge Interoperability

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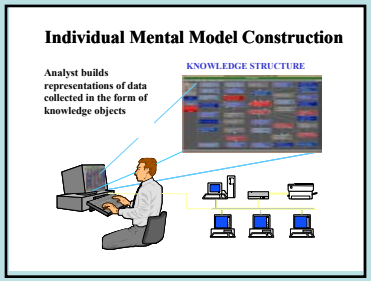
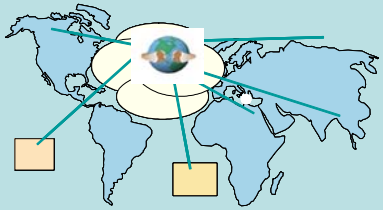
Collaboration and Knowledge Interoperability Program

Individual Knowledge Building



Developing Knowledge Interoperability

Work by teams whose members are separated by space and time.



Program Objective

Understand the cognitive processes underlying team decision making in order to aid and improve team performance in quick-reaction, NDM-type problem solving.

Attaining Shared Understanding

Team Consensus Development

WHAT'S NEW IN TEAMS ?

- **Advanced and ubiquitous socio-technical systems**

- **Globalization and distribution of team members**

- **Multidisciplinary members**

- **Ad-hoc problems with increasing complexity**

- **Accelerated speed of response**

Transformational Team Characteristics

- Unstructured, agile teams
- Distributed and asynchronous relationships
- Heterogeneous members (multidisciplinary, multicultural)
- Ad-hoc, NDM type decision making and problem solving
- Short duration, high stress problems
- Uncertainty in source information
- Dynamic information
- Rotating team members
- Technology supported/collaborating agents

MACROCOGNITION IN TEAMS – A definition

Macrocognition **is defined as the internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a-kind, collaborative problem solving.**

High-level is defined as the process of combining, visualizing, and aggregating information to resolve ambiguity in support of the discovery of new knowledge and relationships

Internalized processes (processes occurring inside the head) are those higher-level mental [cognitive] processes that occur at the individual or the team level, and are not expressed externally (e.g. writing, speaking, gesture), and can only be measured indirectly via qualitative metrics (e.g., questionnaires, cognitive mapping, think aloud protocols, multi-dimensional scaling, etc.), or surrogate quantitative metrics (e.g., pupil size, galvanic skin response, fMRI). These processes can become either fully or partially externalized when they are expressed in a form that relates to other individual's reference/ interpretation systems (e.g. language, icons, gestures, boundary objects)

Externalized processes (processes occurring outside the head) are those higher-level mental [cognitive] processes that occur at the individual or the team level, and which are associated only with actions that are observable and measurable in a consistent, reliable, repeatable manner or through the conventions of the subject domain have standardized meanings. Externalized processes can be measured by various techniques each with their associated metrics, which include discourse analysis, process tracing, automated latent semantic analysis, automated communication flow analysis, and dynamic modeling of communication data

WHY MACROCOGNITON ?

Within the field of cognitive engineering, theorists have proposed the term "macrocognition" to describe how cognition emerges in natural environments. This line of thinking is essentially based upon the work of Cacciabue and Hollnagel (1995) who specifically noted: "Macrocognition refers to the study of the role of cognition in realistic tasks, that is, in interacting with the environment" (p. 57). Klein and colleagues have continued to argue that contextually bound cognitive processes (e.g., sense making, uncertainty management) must be studied in natural settings (Klein et al., 2003). These are environments in which complex and emergent cognitive processes arise (i.e., macrocognitive processes), as opposed to "micro-cognitive" processes described as cognition used in laboratory studies. We extend this theorizing and adopt the more recent thinking on *macrocognition in teams*. Here the term is used to capture cognition in collaborative contexts. In their theoretical and empirical analysis of collaborative problem solving, Warner, Letsky, and Cowen (2005) argue that *macrocognition in teams* encompasses both internalized and externalized processes, which occur during team interaction

MACROCOGNITION - Complementary Perspectives

MACROCOGNITION (in situ)	vs	MACROCOGNITION (in teams)
• Natural settings		• lab-based / experimental
• Task specific		• Extensible
• CTA – based		• Metrics-based
• Practitioners		• Researchers
• Holistic approach		• Reductionist approach
• Product focused / goal directed		• Phenomena focused
• NDM / RPD		• Conceptual model

MACROCOGNITIVE PROCESSES

Individual Knowledge Building: Individual team members ask for clarification of data or information, or respond to clarification requested by other team members.

Team Knowledge Building: All team members participate in clarifying information (e.g., answering a question) to build team knowledge.

Developing Shared Problem Conceptualization: Team members sharing their understanding of problem goals, characteristics of the environment and rules of operating for the generation of quality problem solutions.

Team Consensus Development: Team negotiation of a solution option and collective agreement by team members on a particular option (i.e. each team member does not have to agree on the solution option, but as a team they need to agree on the final option selected).

Outcome Appraisal: Team evaluation (all team members) of selected solution option against problem solving goal. Team revises solution option if option does not meet goal.

Individual Knowledge Building
- **Iterative Information Collection**
- **Individual Task Knowledge Development**
- **Individual Mental Model Development**

Team Knowledge Building
- **Team Pattern Recognition and Trend Analysis**
- **Team Mental Model Development**
- **Recognition of Expertise**
- **Sharing Unique Knowledge**
- **Uncertainty Resolution**
- **Knowledge Interoperability**

Developing Shared Problem Conceptualization
- **Visualization and Representation of Meaning**
- **Building Common Ground**
- **Knowledge Sharing**
- **Knowledge Transfer**
- **Team Shared Understanding**

Team Consensus Development
- **Critical Thinking**
- **Mental Simulation**
- **Intuitive Decision Making**
- **Iterative Information Collection**
- **Solution Option Generation**
- **Storyboading**
- **Team Pattern Recognition & Trend Analysis**
- **Team Negotiation of Solution Alternatives**

Outcome Appraisal
- **Feedback Interpretation**
- **Replanning**
- **Team Pattern Recognition & Trend Analysis**

METRICS

- Cognitive maps
- Discourse analysis
- Think aloud
- Latent Semantic Analysis
- Communication flow analysis
- Dynamic modeling of communication
- Card sorting
- Pre/post questionnaires

RESEARCH CHALLENGES / APPROACH

- REFINE CONCEPTUAL MODEL
- IDENTIFY AND OPERATIONALIZE PROCESSES
- APPLY METRICS TO EMPIRICALLY VALIDATE CONSTRUCTS
- PREDICT IMPACT ON TEAM PERFORMANCE
- MAKE FINDINGS EXTENSIBLE

STEPS FORWARD

- MULTI-TRAIT MULTI-METHOD APPROACH
- TECHNOLOGY DEMOS OF PROCESS AIDS
- TESTBEDS / SCENARIOS
- INTERIM TOOLS
- GUIDELINES, MODELS

BACK UP SLIDES

CKI Program Structure (FY06/07)

Representation and Transfer of Meaning

• Electronic Card Wall (EWALL)	**MIT**
• Collaboration and Meaning Analysis Process (C-MAP)	**UTenn**
• Decision Making Constructs in a Distributed Environment (DCODE)	**SPAWAR**
• Communication in Team Cognition (COMTC)	**ASU**
• Augmented Reality Visualizations for Shared Understanding (AUGVID)	**UCSD**
• Sys for Understanding and Measuring Macrocognition in Teams (SUMMIT) **MURI**	**UCF**

Attaining Shared Understanding

• Mental Model Convergence (MMC)	**UMASS**
• Common Ground in Geo-Collaboration (CGGC)	**Penn State**
• Automated Comm Analysis for Interactive SA Assessment (ASA) 04-119 **SBIR**	**SA Tech**
• Instrument for Measuring and Advancing Group SA (IMAGES) 04-T026 **STTR**	**Aptima**
• Human-Centric Architecture for Net-Centric Operations (DCCS) 04 –T026 **STTR**	**PSE**
• Processes in Complex Team Problem Solving (TPS)	**UCF**

Team Consensus Building

• Collaborative Critical Thinking (CCT) (CENTER) 00-086 **SBIR**	**Aptima**
• Macro Cognition in Team Collaboration (MCTC)	**NAVAIR**
• Shared Information Virtual Surfaces (SIVS)	**Col. State**
• Joint Intelligence Graphical Situation Awareness Web (JIGSAW) 04-116 **SBIR**	**PSE**
• Enhancing Tactical Decision-Making in Navy Seal Ops (SLATE) 05-069 **SBIR**	**PSE**
• Integrated Dec Space Model for Cultural Diff (IDSM) (IDecS) 03-112 **SBIR**	**PSE**
• NPS Testbed for Team Collaboration (NPSTB)	**NPS**

COLLABORATION AND KNOWLEDGE MANAGEMENT (CKM) PROGRAM

MODEL OF TEAM COLLABORATION

FOCUS ON MACRO-COGNITON

Problem Area Characteristics

Collaborative Situation Parameters:

- time pressure
- information/knowledge uncertainty
- dynamic information
- large amount of knowledge (cognitive overload)
- human-agent interface complexity

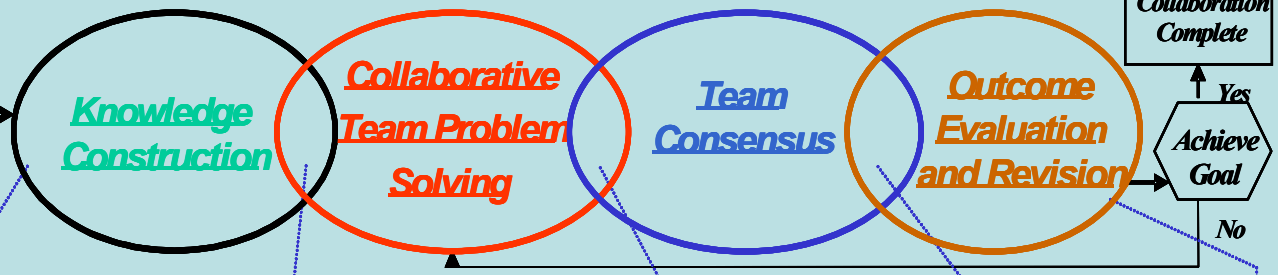
Team Types

- asynchronous
- distributed
- culturally diverse
- heterogeneous knowledge
- unique roles
- command structure (hierarchical vs. flat)
- rotating team members

Operational Tasks

- team decision making, COA selection
- develop shared understanding
- intelligence analysis (team data processing)

Collaboration Stages & Cognitive Processes



Meta-Cognitive:

- individual conversion of data to knowledge
- team integration of individual knowledge for common understanding
- team agreement on a common solution
- solution adjustment to fit goals and exit criteria

Macro-Cognitive:

- individual mental model construction
- knowledge interoperability development
- individual task knowledge development
- team knowledge development
- individual knowledge object development
- individual visualization and representation of meaning
- knowledge interoperability development
- iterative information collection and analysis
- team shared understanding development
- develop, rationalize, & visualize solution alternatives
- convergence of individual mental models to team mental model
- individual task knowledge development
- team knowledge development
- team negotiation of solution alternatives
- team pattern recognition
- team shared understanding development
- convergence of individual mental models
- critical thinking
- sharing hidden knowledge
- individual task knowledge development
- team task knowledge development
- compare problem solution against goals
- team shared understanding development
- convergence of individual mental models of solution
- analyze, revise output

Mechanisms for achieving Meta and Macro Cognitive Processes (applies to all stages)

- **Verbal communications** presenting and discussing individual information, discussing team generated information questioning, agreeing / disagreeing, negotiating perspectives, discussing possible solutions, providing rationale
- **Non-Verbal communications** facial expressions, voice clues (vocal paralanguage), hand gestures, body movements (kinesics) touch (haptics), personal space, drawing, text messages, augmented video, affordances (cognition in objects).

Defense Transformation / NCO / FORCEnet

A Need for Agile Teams

Fifteen percent increase in U.S. Special Operations Forces (SOF) including secret Delta Force operatives skilled in counterterrorism.

A one-third increase in Army Special Forces battalions, whose troops are trained in languages and to work with indigenous fighters

"SOF will increase their capacity to perform indirect and clandestine operations in politically sensitive environments and denied area

"SOF will have the capacity to operate in dozens of countries simultaneously" and will build relationships with "foreign military and security forces,"

The creation of small teams of operatives assigned to "detect, locate, and render safe" nuclear, chemical and biological weapons -- as well as to prevent their transfer from terrorist groups.

Quadrennial Defense Review

Significance for Team Decision Making

Asymmetric warfare, including increasing information uncertainty, increasing multidisciplinary and multicultural participants and complex political considerations will dictate more human analysis and intervention.

As decision making becomes more time-compressed, individuals and teams will have to operate with less (technology and human) advisory support.

Quick response, agile, mixed discipline teams will become an important force multiplier

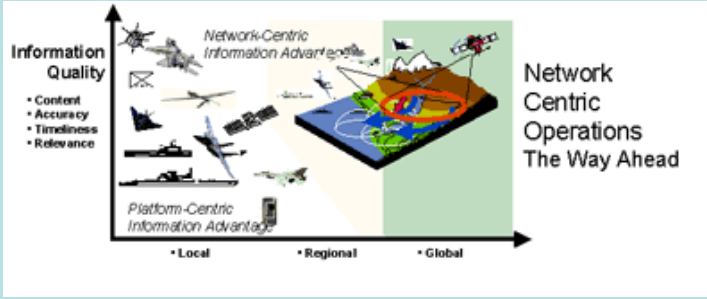
Research Challenge:

Understand and Improve Transitional Team Performance

Defense Transformation / NCO / FORCEnet

…. information operation and ***networking and connecting things in ways that they function totally differently than they had previously*** …….if that's possible, the ***single-most transforming thing*** in our force will not be a weapon system, but ***a set of interconnections*** and a substantially enhanced capability because of that awareness.“ - ***Secretary of Defense Donald H. Rumsfeld***

"If you are not interoperable, you are not on the net, you are not contributing, you are not benefiting, and you are not part of the information age - Vice Adm Art Cebrowski [DoD Director, Force Transformation



Collaboration technologies assist the operator in making sense out of the data he or she pulls. To successfully operate within our increasingly complex and interrelated world, unprecedented combinations of subject matter experts are often needed to make sense out of special situations. These experts are not likely to be found in any one single unit or organization. Therefore, the ability to pull expertise from both within a unit as well as from across the Department is an important value-added feature of net-centricity.